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Antarctic Meteor Scatter Test, December 1992

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PREFACE

This research was conducted under a grant from the National Science Foundation, Office of Polar Program (Patrick Smith), Technical Event Number T-306, and the Office of Naval Research (Dr. Sherman Gee), PE62232, RC32C18. The NUWC Project Number is A50400, Principal Investigator, Joseph R. Katan (Code 3411).

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This report documents the 1992 Antarctic Meteor Scatter Test. The purpose of the test was to evaluate the performance of a meteor scatter communications link in high southern latitudes.

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ANTARCTIC METEOR SCATTER TEST, DECEMBER 1992

INTRODUCTION

The purpose of the meteor scatter test was to evaluate the performance of a meteor scatter communications link in high southern latitudes. The distance chosen [875 statute miles (1409 km)] is representative of the distances of various U.S. field camps from McMurdo Station, Antarctica, while being well within the maximum possible meteor scatter range of about 1200 miles (2000 km). Both high power commercial gear typical of a base station and a lower power unit that might be useful at a field camp were tested. The communications link was used to collect data on message delivery times and the time distribution of received message packets. The testing was to be accomplished over a 10-day period in mid-November 1992.

The communications link tested in the Antarctic meteor scatter test was the 875 statute mile (1409 km) path between McMurdo Station (78°S 167°E) and Byrd Surface Camp, which is located in Marie Byrd Land (80°S 120°W). Both sites used portable Hadron Meteor Burst transceivers* with approximately 1,000 W output power and receive preamplifiers with a 3 dB noise figure mounted directly at the receive antennas. Two separate 5-element Yagi antennas, mounted horizontally 30 feet (9.1 m) above the surface, were used for transmitting and receiving. A 200 W transceiver and vertical half-wave J-pole antennas were also installed at McMurdo. (See the appendix for more details on equipment.) Each transceiver was connected to a Compaq computer which provided control, message handling, and data storage functions. The computers also contained digitizing cards which were used to record the raw video output of spectrum analyzers that were connected to intermediate frequency (IF) outputs on each transceiver. The link was operated full-duplex on two frequencies in the 40 MHz to 50 MHz band.

DESCRIPTION OF MCMURDO STATION

PHYSICAL DETAILS

At McMurdo, the gear was installed at the small wooden building known as Little House, which is located next door to COSRAY on the road between the McMurdo and Scott bases (see map, figure 1). This location was chosen because it was well away from the electromagnetic interference (EMI) problems of the downtown area of McMurdo and had an unobstructed view of the horizon from 300 feet (91 m) above sea level in the direction of Byrd Surface Camp, which is across the Ross Ice Shelf. Little House was unoccupied, heated, and had sufficient electric power. The ground at Little House was bare, frozen, volcanic rock which sloped down to the ice shelf. The transmit Yagi was mounted on an existing 30-foot (91-m) tower located about 100 feet (30 m) down the slope from Little House. It was fed with a 7/8-inch (2.2-cm) diameter heliax. The receive Yagi and preamplifier were mounted on a pipe attached to an existing platform at roof level on top of Little House. Although the McMurdo HF transmit antennas were located on a plateau overlooking Little House, they caused very little EMI during the test. (Figure 2 shows the layout.) The only EMI caused by our transmissions was to an Estorline-Angus chart recorder being used at COSRAY to collect data from an ozone measuring device. This EMI was eliminated by placing a ferrite isolator on the power and input lines. Several days of testing for EMI confirmed the site's suitability.

*Hadron no longer exists. Fewer than 20 units were manufactured.

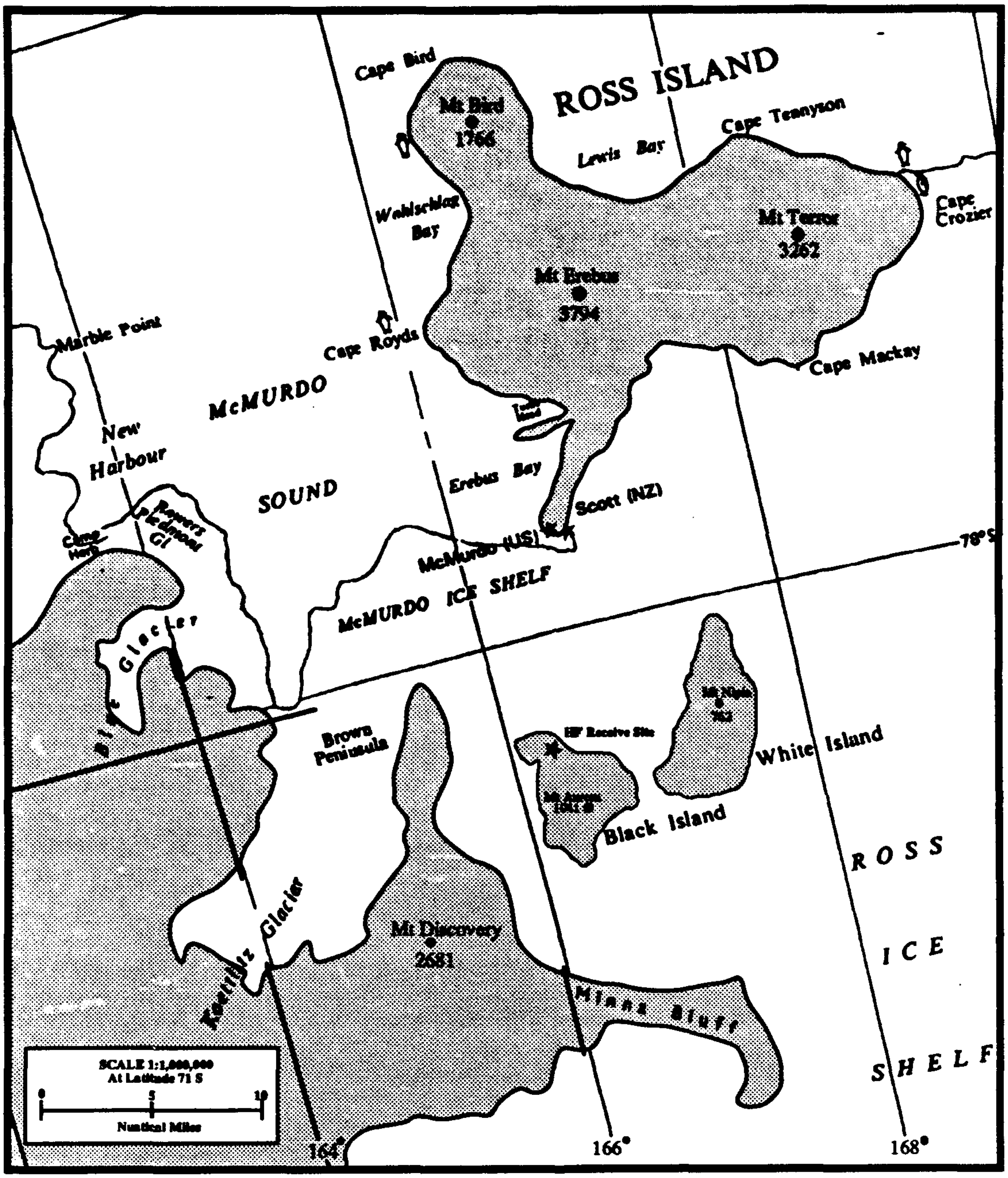

Figure 1. Map of Test Site

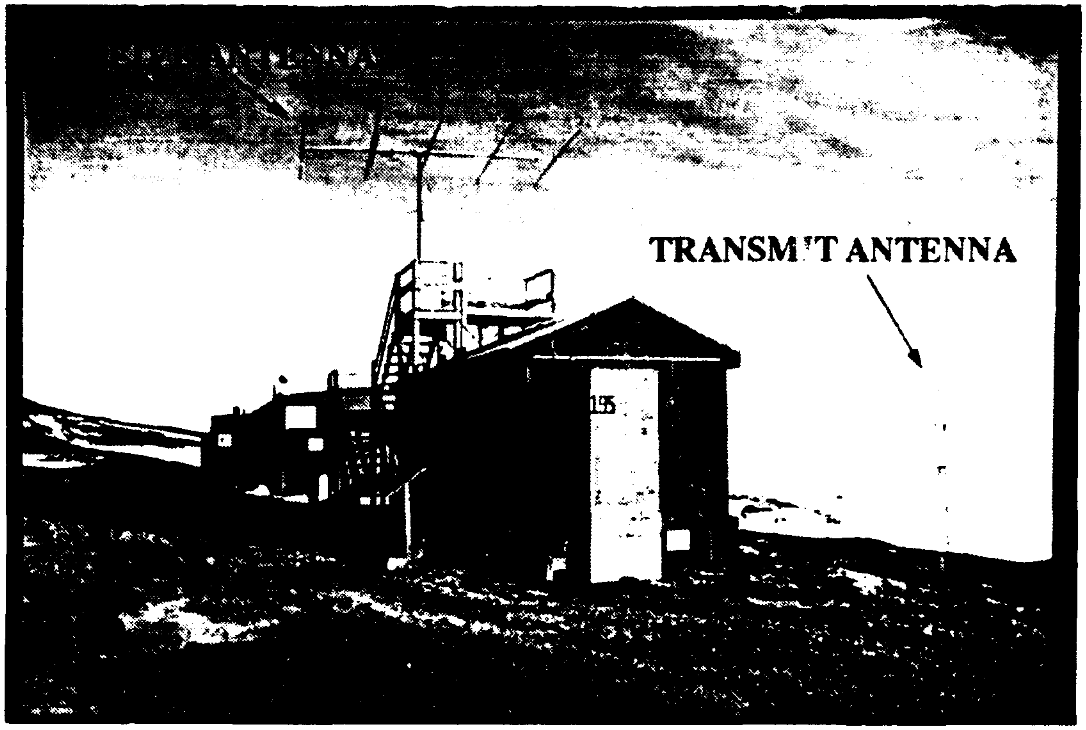

Figure 2A. Photograph of McMurdo Station

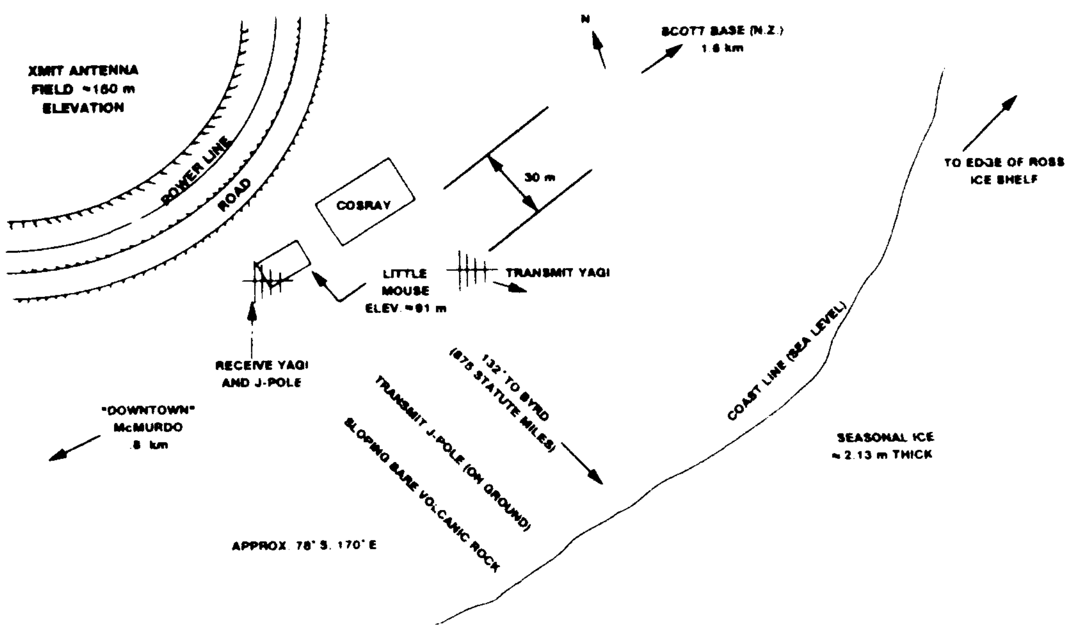

Figure 2B. Layout of McMurdo Station

Figure 2. Photograph and Layout of McMurdo Station

ELECTRICAL DETAILS

Figure 3 is a block diagram of the communications link at McMurdo. The Hadron transceivers used a modified packet radio protocol (HX.25) designed for maximum throughput in the meteor scatter mode. The basic data rate was 9600 baud, which was reduced to 4800 baud by the use of forward error correction (FEC).

A packet length of 45 milliseconds, with 20 message characters per packet, was used for most of the testing. The transmitter repeated up to seven different packets until one was acknowledged by a signal received from the other end of the link, which caused the acknowledged packet to be replaced by a new one. Transmissions ceased only when the last packet was sent. Since this system was full-duplex, messages could be passed in both directions simultaneously.

A test mode was also used allowing transmission of 45 millisecond "dummy" packets (called "RAK" frames), which did not require acknowledgment. The RAK frames were used to test each one-way path of the link separately by simply counting the number of correctly received RAK frames versus time. This was done simultaneously on both paths during the testing.

The Hadron transceivers used 1,000 W (or 200 W) class-C RF power amplifiers with a low-pass filter located near the antenna to remove harmonics and a filter in the driver to remove noise and interference near the receiving frequency. The modulation was minimum shift keying (MSK), which is compatible with the efficient class-C mode used.

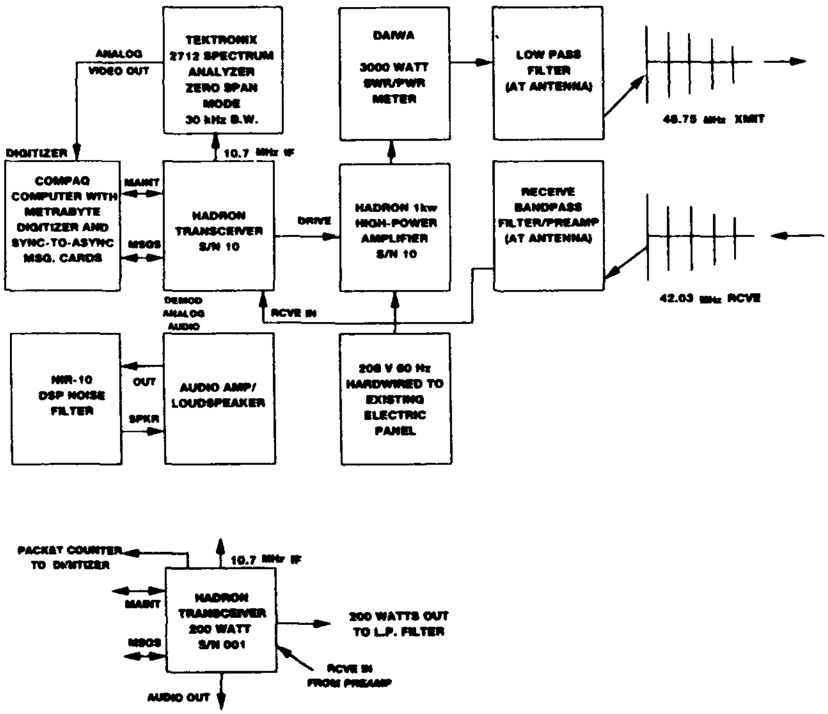

Figure 3. Block Diagram of Communications Link at McMurdo Station

The receiving preamplifier was preceded by a sharply tuned bandpass filter to reject interfering signals, especially signals from the transmitter located only 100 feet (30 m) and 7 MHz away. No receiver EMI was observed from any source when using the 1,000 W transceiver, except for momentary noise bursts from the HF transmitters located on the hill behind Little House. There was an unexplained 4 to 5 dB increase in receiver noise when the 200 W Hadron transceiver was used.

The raw audio output proved to be very useful for detecting equipment problems, EMI and the type of propagation occurring. It became easy to recognize when the other station was on the air and to differentiate between the sounds of messages and RAK frames.

The 10.7 MHz IF signal was removed prior to the automatic gain control (AGC) to provide a linear output. At this point, the bandwidth was approximately 30 kHz due to the 9600 baud modulation rate, but the video output contained only noise and the slowly varying envelope of the incoming meteor burst, which may have a rise time of about 50 milliseconds. The signal was digitized by a Metrabyte card, which was set to 100 samples per second.

The Compaq computer had two expansion slots: one that held the Metrabyte card and one for the synchronous data to asynchronous translator for the Hadron transceiver. The Compaq computer was used to run a Hadron-developed program called HDCOMM++ (Version 3.71), which provided hardware control and message handling functions. Control functions included adjustment of transmit/receive frequencies, setting of packet length, FEC on/off selection, and test modes for transmission, reception, and counting of RAK frames. Message handling included transmission of canned messages and messages composed on a built-in word processor. Also included was repeated sending of the same message for test purposes, message bit error rate (BER) analysis, and display and storage of incoming messages. The digitized IF data was stored on the hard disk and later copied onto 750 kilobyte floppies. The low density of data storage limited the amount of data that could be taken.

DESCRIPTION OF BYRD SURFACE CAMP

PHYSICAL DETAILS

The primary reason for testing at the Byrd Surface Camp, rather than at South Pole or CASERTZ (a geologic field camp) which are roughly the same distance from McMurdo, was to avoid mutual EMI problems. Since the only potential camp interference was to or from the HF communications single sideband (SSB) radio, the Meteor Scatter gear was located as far from the HF antenna (a conical monopole) as possible and the transmit Yagi was located as far away as the available feed line permitted (see figure 2). The TACAN shack was usable because the TACAN gear was not in use and heat, light, and 120/208 VAC were available. Byrd Camp is located on a featureless plain of windswept, snow-covered ice at an elevation of about 5,000 feet (1524 m). The entire camp was constructed on a 25-foot (7.6-m) high snow berm to keep it from being completely buried during the winter when it is not occupied. The primary function of the camp is to act as a safety and refueling stop for the LC-130 ski equipped planes supporting distant camps. The major activity of the camp, operated by Navy Seabees, was to keep the runway clear, but a lot of effort was expended to remove the past winter's snow from the camp and to repair damage. Riggers helped erect the two 30-foot (9.1 m) towers for the Yagi antennas using buried plywood anchors. The transmit antenna was fed with 400 feet (122 m) of 7/8 inch (2.2 cm) diameter Heliax cable. The receiving antenna was located away from the camp, approximately 300 feet (91 m) from the transmit antenna (see figure 4). Both antennas had an unobstructed view of the horizon. Total setup time was 2 days.

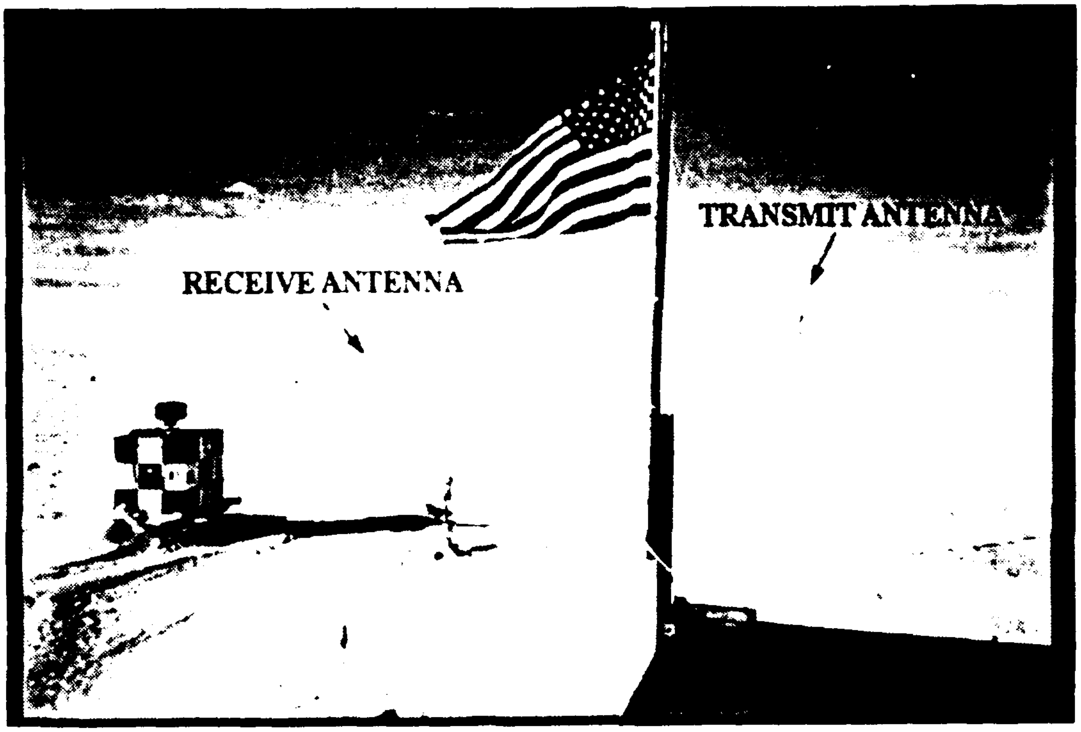

Figure 4A Photograph of Byrd Surface Camp

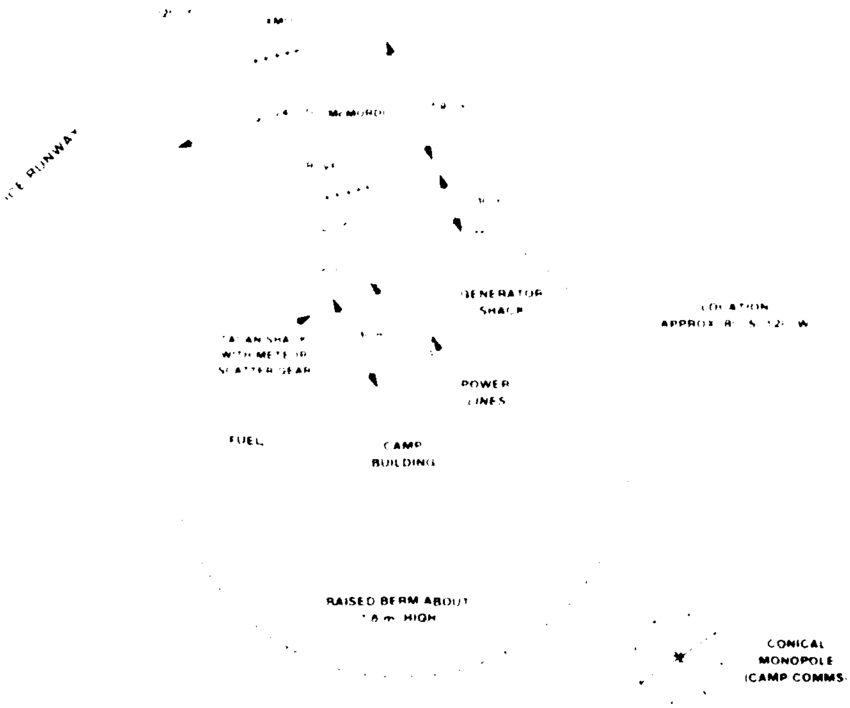

Figure 4B Layout of Byrd Surface Camp

Figure 4 Photograph and Layout of Byrd Surface Camp

ELECTRICAL DETAILS

Figure 5 is a block diagram of the communications link at the Byrd camp. The test setup at Byrd was similar to McMurdo, however, there was no 200 W transceiver or vertical antennas. With the wide antenna spacing, there was never a hint of interference from the transmitted signal. There was no interference transmitting or receiving camp communications, and no noise from the generator. The watt meter gave only a relative power reading, but was still useful and the external loudspeaker gave superior audio, which aided in detection of "continuous" modes. The large size of the Byrd computer's hard disk allowed many hours of IF data to be recorded. All other details were the same as McMurdo.

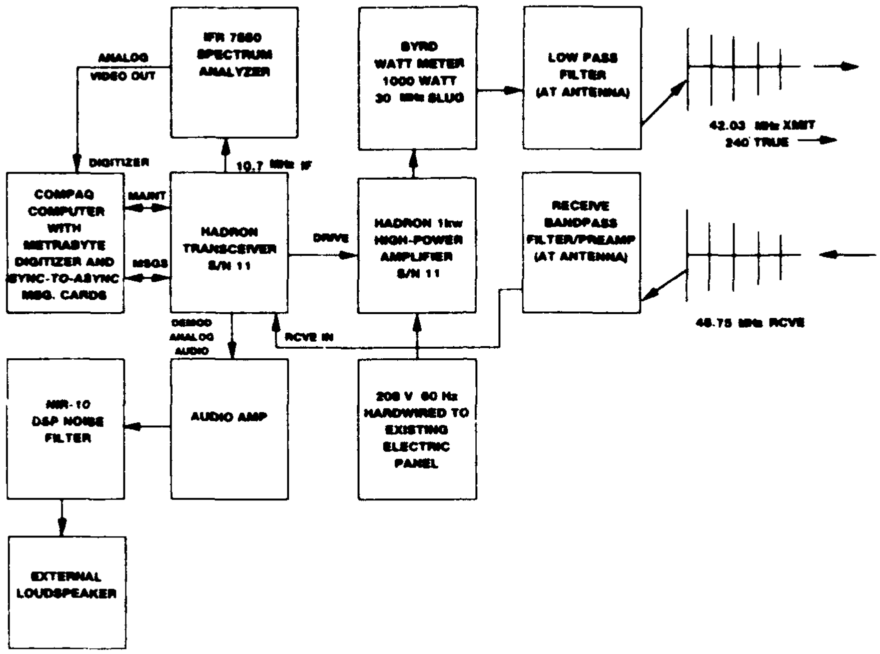

Figure 5. Block Diagram of Communications Link at Byrd Surface Camp

METEOR SCATTER TEST SET-UP

The communications link became fully operational late on 2 December 1992, and testing continued through 7 December 1992. There was an initial problem at Byrd Station that caused an automatic shutdown of the 1,000 W amplifier from a "low power" error. Low power line voltage of 194 to 203 volts may have played a role in the shutdown. This was an occasional problem throughout the testing and became chronic on both ends of the link on the final day. Software errors in the Hadron operating system and in the HDCOMM++ communications program appeared from time to time. (This was probably triggered by improperly received packets.) The Hadron equipment would not function properly on a long-term basis without assistance. (Hadron no longer manufactures this equipment.)

After the initial "chatting" over the link, it was decided to send RAK frames at both ends overnight and record IF data. It became obvious the next day that the propagation was more than meteor bursts. Using the loudspeaker, it was possible to hear the incoming signal weakly but continuously in the background for long periods of time, which was probably ionoscatter at this distance. There were also periods ranging from seconds to minutes when the signal would become strong enough to pass messages, probably Sporadic-E. The remaining transmissions

were meteor bursts of varying duration and intensity. There was an occasional burst of EMI in the form of a high pitched "buzz" which was probably meteor scatter from the 60 MHz broadband ice penetrating radar being used at CASERTZ located about 105 statute miles (169 km) away from Byrd Camp, but not in a direct line to McMurdo.

The remainder of the test time was split between sending and receiving RAK frames to measure path availability and exchanging groups of messages of varying lengths to obtain a realistic measure of message throughput for this type of gear. Most of the tests were conducted using the 1,000 W transmitters and Yagi antennas at both ends. Limited tests were conducted with the 200 W unit despite its EMI problem and also with the vertical J-pole antennas.

The Hadron equipment was set up to generate RAK packets identical to normal message transceiver frames, i.e., 45 milliseconds long, 20 dummy message characters (bytes), and FEC. The 1,000 W units and horizontal Yagis were used for the entire time. The measured transmit rate was 0.056 sec per RAK frame. Each packet correctly received, incremented a counter displayed on the screen, and the observer simply noted the time and count periodically in a logbook. The RAK frames were used to test each one-way path of the link by simply counting the number of correctly received RAK framed versus time. This was done simultaneously in both directions during the testing. The combined data for each direction was used to calculate the average path availability during the test period as shown in table 1. The same data is broken down into four-hour blocks (except eight hours overnight) to show the diurnal variation in table 2 and figure 6.

Table 1. Average Path Availability

Path	Total RAK Frames	Total Listening Time (min.)	Total RAK Time (min.)	Average Path Availability
Received at Byrd	379348	2298	354	15.4%
Received at McMurdo	145359	1517	136	9.0%
Received Both Ways	524707	3815	490	12.8%

Table 2. Diurnal Variation of Path Availability

	Local Time (New Zealand Daylight, +13 Hours)				
	0000-0800	0800-1200	1200-1600	1600-2000	2000-2400
Received at Byrd					
Total RAK Frames	205189	75248	46121	28548	34251
Total Time (min.)	1024	362	380	377	373
Path Availability	18.7%	19.4%	11.3%	7.1%	8.6%
Received at McMurdo					
Total RAK Frames	49788	4273	58922	11251	106
Total Time (min.)	650	30*	368	243	4*
Path Availability	7.1%	13.3%	14.9%	4.3%	2.5%
Received Both Ways					
Total RAK Frames	254977	79521	105043	39799	34357
Total Time (min.)	1674	392	748	620	377
Path Availability	14.2%	18.9%	13.1%	6.0%	8.5%

*Time considered too short.

The test was scheduled to last ten days, but was terminated prematurely after six days because the gear at both ends of the link became unreliable and would only operate properly for short periods of time. The McMurdo site eventually required a computer reset after every message. The 1,000 W transmitter at Byrd would require fifteen minutes to restart after it shut down during the frequent resets of the Hadron transceiver. The RAK frame generators at both ends became intermittent and would revert to a carrier with square wave modulation, which would cause errors in the count.

DATA ANALYSIS

PATH AVAILABILITY

December is a time of medium meteor arrival rates. Diurnal variations in meteor rates and trail duration combine to cause a broad maximum in path availability early in the day and a minimum at around 1800 hours local time, as shown in figure 6. The path availability was much greater than the expected rate of 2.5 to 5% for meteor scatter alone.

Ionoscatter is a weak but steady forward scatter from the D-region, which is much stronger in the summer than winter with a diurnal variation of a broad maximum early in the day. The daytime effect is apparently caused by turbulence or wind shear which causes irregularities in the electron distribution at about a height of 43 miles (70 km). The weaker nighttime effect is thought to be caused by the influx of meteors.

Sporadic-E reflections are also present in the summer, mostly during the daylight hours. This mode is caused by wind shear which produces rapidly drifting clouds of ions at altitudes slightly above 62 miles (100 km). Sporadic-E causes dramatic signal enhancement for brief periods of time up to a few minutes in length. Auroral sporadic-E can also occur in polar regions, mainly at night.

The total path availability is the sum of all the above mentioned modes, none of which are affected by the sunspot cycle. The high path availability in the morning hours and during the austral summer make scatter mode propagation most attractive as a backup for HF communications between the main Antarctic stations and field camps.

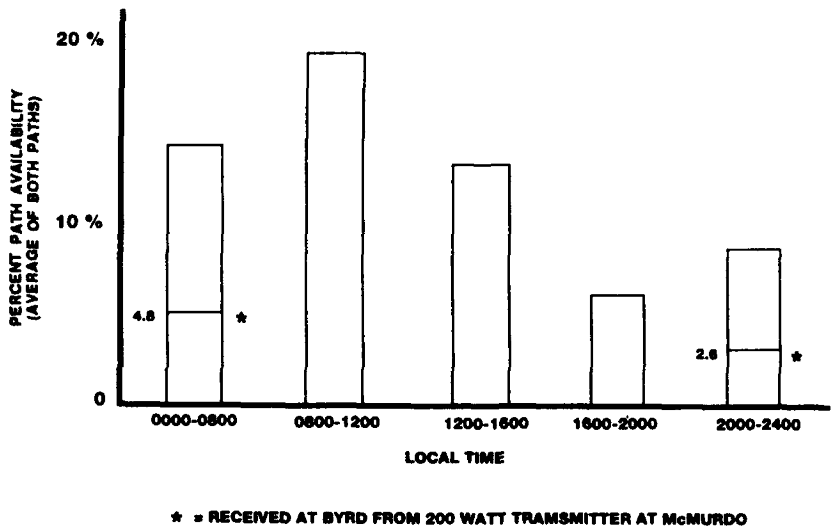

Figure 6. Diurnal Variation of Path Availability

MESSAGE DATA RATE

Test messages of varying lengths were sent in both directions between Byrd and McMurdo to measure the actual throughput of the Hadron gear when passing typical traffic. Each "canned" message was repeated continuously for varied periods of time and the analysis performed by looking at the directory of received files which were all time stamped at the time of reception. The length of time taken to receive each message (except for the first) was determined by subtracting the time from the receive time of the previous message. Bytes per message divided by the time taken to receive it gave the data rate. Minor reception errors were ignored. Message lengths of 397, 1805, and 1892 bytes were used. Table 3 gives the average message data rates for each direction. Only messages sent/received using the 1,000 W Hadron units and the Yagi antennas are included in the table data. Data from one brief long period of continuous transmission was deleted because it was not representative of typical throughput.

Table 3. Message Data Rate Summary

Path	Total Data Message Byes	Total Data Minutes	Bytes/ Minute	Words/ Minute
Received at Byrd	183992	445	413	83
Received at McMurdo	247743	448	448	90
Average Both Directions	431735	998	433	87

There were wide variations in message throughput during the test period with no obvious correlation to time of day, message length or path direction. Table 4 is a list of all messages for time periods when identical messages were received simultaneously at both sites. This data illustrates the wide variation in throughput although there is not enough data to properly analyze these variations.

Unacknowledged RAK test frames were transmitted continually from both sites during times when the radios were unmanned such as most nights and during meal times. The greater RAK data (3815 minutes versus 998 minutes of test messages) that was measured greatly improved the quantitative analysis of the path availability in each direction.

Table 4. Comparison of Message Two-Direction Data Rate for the Same Time Periods

UTC Date	Received at Byrd UTC Start Time	Received at Byrd Elapsed Time (min.)	Received at Byrd Words Per Min.	Received at McMurdo UTC Start Time	Received at McMurdo Elapsed Time (min.)	Received at McMurdo Words Per Min.	
12/2/92	2053	9	1135	2053	6	1925	
12/3/92	0726	51	68	0726	48	38	
12/4/92	0325	24	95	0325	24	271	
12/4/92	0656	20	20	0646	22	40	200 W at McMurdo,
12/5/92	0057	29	49	0049	32	32	Yagis at both ends.
12/6/92	0214	59	59	0211	62	40	
12/6/92	0334	39	75	0323	50	65	
12/6/92	0920	77	91	0920	79	60	
12/6/92	0425	12	40	0423	13	220	

Note: All testing used 1,000 W Hadron meteor scatter transceivers and 5-element Yagi antennas at both ends, except as noted. FEC was in use with 20 characters per packet (5 characters per word is assumed).

The measured throughput of 87 words per minute is more than adequate for normal levels of field camp to base camp communications but is too slow to pass large amounts of scientific data as might be desired by science groups. Operating in a strictly meteor burst mode, the Hadron equipment is specified to have a nominal throughput of 50 words per minute with forward error correction turned on which is lower then the measured value. Winter throughput rates would probably be less than half of those measured during this summer test. The lack of aircraft flights and minimal camp activity in the winter might lessen the need for the higher rates that are achievable in the summer.

MESSAGE BIT ERROR RATE (BER)

All messages received at each end of the link were stored on each computer's hard disk. The messages were divided into three groups: short, real-time maintenance messages; medium length "canned" messages; and long "canned" messages. Each message was checked for accuracy and the number of correct and faulty bytes were recorded. Most errors consisted of entire 20 character packets that were received incorrectly and often the remainder of the message following the error was lost. Table 5 is a summary of the message BER (more correctly identified as byte error rate) for the messages received at each station and table 6 lists the average BER for the two directions.

Table 5. Summary of BER

Received at Byrd Surface Camp					Received at McMurdo				
Message Length (Byte)	Total Messages	BER (%)	Messages with Errors	Percent of Msgs with Errors	Message Length (Byte)	Total Messages	BER (%)	Msgs with Errors	Percent of Msgs with Errors
<200 Avg 80	109	3.1%	4	3.7%	<200 Avg 117	94	0.6%	1	1.1%
397	276	3.4%	28*	10.1%	397	416	5.2%	65†	15.6%
1892	60	7.9%	10	16.7%	1805	64	3.0%	5	7.8%

* Messages with the last character missing = 7.
† Messages with the last character missing = 26.

Table 6. Average BER for Both Directions Combined

Message Length	Number of Messages	2-Way Average BER
<200 Bytes Avg 97 Bytes	203	1.7%
397 Bytes	692	4.4%
1805-1892 Bytes	124	5.4%
All Msgs Combined	1001	4.7%

As might be expected, the data in table 6 indicates that the average error rate (i.e., BER) increases with message length. Short messages can be received on a single meteor trail, which enhances the chances of correct reception. This is a good argument for message brevity and for repeating messages twice to ensure reception, especially at an unoccupied station.

The 4.7% BER for all received messages was higher than was expected. Equipment from other companies may perform more successfully, but at a slower data rate. The synchronous demodulation scheme might be partly to blame for loss of the entire message after a single error occurs because an incorrectly received packet would tend to disrupt the synchronization of the following packets.

TESTS WITH LOW POWER AND OTHER ANTENNAS

Initial testing at Byrd was conducted using the Yagi antennas Some testing was done using a 200 W Hadron transceiver at McMurdo and a 1,000 W transceiver at Byrd station with Yagi antennas connected at both ends. Figure 6 illustrates the significant reduction in path availability resulting from the reduction in transmit power. Message throughput also suffered as shown in figure 5, even though the acknowledgment path utilized 1000 W. This test simulated a base (Byrd) to field camp (McMurdo) communications link where high power could not be used at the camp but high gain Yagis could still be erected.

A short test was conducted using the 200 W transceiver connected to two J-pole antennas which are "end-fed" vertical dipoles. Only a few RAK frames were received at each site using this configuration over a one-hour time period and, because of this, no message exchanges were attempted. The purpose of this J-pole configuration was to best simulate the characteristics of a remote buoy or a small camp set-up. The low rate of throughput is due to the low gain (10 dB less) of the J-pole compared to the Yagi combined with cross-polarization loss (magnitude unknown) between the horizontal Yagi and the vertical J-pole. It was not possible to change the antenna polarization at Byrd. A reduced data throughput was expected with the J-poles, but results were much poorer than expected.

DIGITIZED RAW IF DATA

Many hours of RAK frame IF data were recorded digitally at each end of the link and stored on computer disks and on the computer's hard drives. This was done without lengthening the test or interfering with the primary purpose of determining the suitability of this type of equipment for use in the Antarctic. This data, which includes signal and noise spectral magnitudes, can be reduced to give statistical data on trail lengths, signal strengths and propagation modes.

CONCLUSIONS AND RECOMMENDATIONS

The ionosphere in Antarctica will support reliable scatter mode communications over an 875 mile (1409 km) coast-to-inland path like the McMurdo-to-Byrd path tested for this report. The limit in communication range is expected to be about 1000 statute miles (1610 km). Transmit power levels of 1,000 W are required for moderate throughput (87 words per minute) but 200 W transmitters can be used resulting in reduced throughput. High-gain Yagi antennas are necessary to get usable levels of throughput and they may in fact help with local EMI reduction due to increased isolation between transmit and receive antennas resulting from their narrower beam widths. Summer morning hours (0800-1200) are when the highest levels of data throughput are obtainable. Wintertime throughput levels will be less then the levels that are achievable during the summer. The propagation modes utilized during this test were meteor scatter and occasional sporadic-E scatter. Continuous weak ionoscatter signals could be heard much of the day on the audio channel output, but these signals were not usually strong enough to break the signal threshold level required to transfer data. The 87 words per minute measured data throughput level resulted from a combination of signals from all three propagation modes. A small ionospheric disturbance that caused some disruption of HF communications went unnoticed during this test, which demon-strates the backup capability of the scatter mode.

The Hadron meteor burst radio gear (no longer commercially available) was the only known portable high power (1,000 W) equipment available at the time of this test. Portability is necessary for Antarctic field camp use of such a system. Several drawbacks in the Hadron gear design that became apparent from this test are listed below:

1. The gear uses unaddressed packets to reduce overhead and therefore cannot be used in a network with multiple stations where three or more transceivers are operating at once.

2. The 40-50 MHz frequencies utilized are more susceptible to PCA blackouts than higher meteor burst compatible frequencies. Fequencies in the 60 to 80 MHz band would also require smaller antennas which is more desirable for field operations.

3. The average measured bit error rate of 4.7% is quite high compared to standard data communication links although the measured value of 1.7% for short message length may be acceptable.

The best use of meteor scatter gear in the Antarctic is as backup equipment to routine HF communications to remote camps. The meteor scatter link should not be affected by sunspot activity and only minimally affected by ionospheric disturbances while the HF link may become completely unusable during these events. This particular type of meteor scatter link is not suitable for trans-mission of large amounts of data because of the slow data throughput rate and high BER of the system.

Commercial sources of meteor scatter gear will have to be investigated before systems can be purchased for deployment since the tested gear is no longer available and aspects of its

operation need to be improved. The transceiver power requirements are a primary consideration in the suitability of any candidate system because of the required output power (200-1000 W) and the unreliable nature of the remote site power sources. It would be advantageous, from a power conservation point of view, to have a remote field camp transceiver operate as a "slave" node where it only transmitted briefly to acknowledge receipt of a packet (and perhaps send one of its own) when it knows that the "master" station will hear it. If the portable transceiver is designed to operate as a low duty cycle "slave," then it could be built compact and lightweight.

The existence of multiple field camps in Antarctica necessitates the use of networked communication links. The unaddressed packets used by the Hadron meteor scatter gear are not compatible with network operation.

APPENDIX

SPECIFICATIONS OF HADRON METEOR BURST TRANSCEIVERS MBC-8221 (200 W) AND MBC-8661 (1000 W)

TRANSMITTER

Power Output:	Nominal 200 or 1000 W into 50 ohms
Duty Cycle:	0 to 100%
Spurious and Harmonic Levels:	< –60 dBc
Bandwidth:	25 kHz

RECEIVER

Noise Figure	3 dB maximum
AGC Range	> 40 dB
Maximum Composite Input Signal (at 1 dB compression)	–20 dBm

SYSTEM

Forward Error Correction (FEC)	Rate 1/2 Golay
Message Terminal Data Rate	9600 bps
Transmitted Data Rate	9600 bps (4800 with FEC)
Average Data Throughput	100 words per minute (no FEC)
Bit Error Rate (BER)	$<1 \times 10^{-4}$ at Eg/No = 8 dB (with FEC)
Modulation Type:	Serial minimum shift keying (MSK)
Operational Modes:	Continuous full-duplex or probe and wait (master/slave) full-duplex.
Carrier Frequency	40-50 Mhz in 20-kHz steps

ANTENNAS

Type:	5 element Yagi
Gain:	12 dB
Frequency:	40-50 MHz (pretuned)
Bandwidth:	1 MHz
Power Input Limit:	2000 W
Mast:	2 inch (5.08 cm) diameter, minimum 15 feet (4.6 m) above roof top and all obstructions.
Weight:	35 lb (15.75 kg) packed for transport

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